Notes on Incandescent Street Lighting

WESTINGHOUSE ELECTRIC & MFG. CO.
PITTSBURG, PA.

NOTES ON

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By K. C. Randall.

In small towns and villages, outlying districts, crooked or heavily shaded streets and alleys, the incandescent street lamp when located at short intervals furnishes an illumination which, while less intense, is more uniformly distributed than with the arc system. Therefore, while the arc system is to be preferred for such service as lighting business streets, docks, large yards, etc., the incandescent system in general finds its best application under conditions similar to those mentioned above.

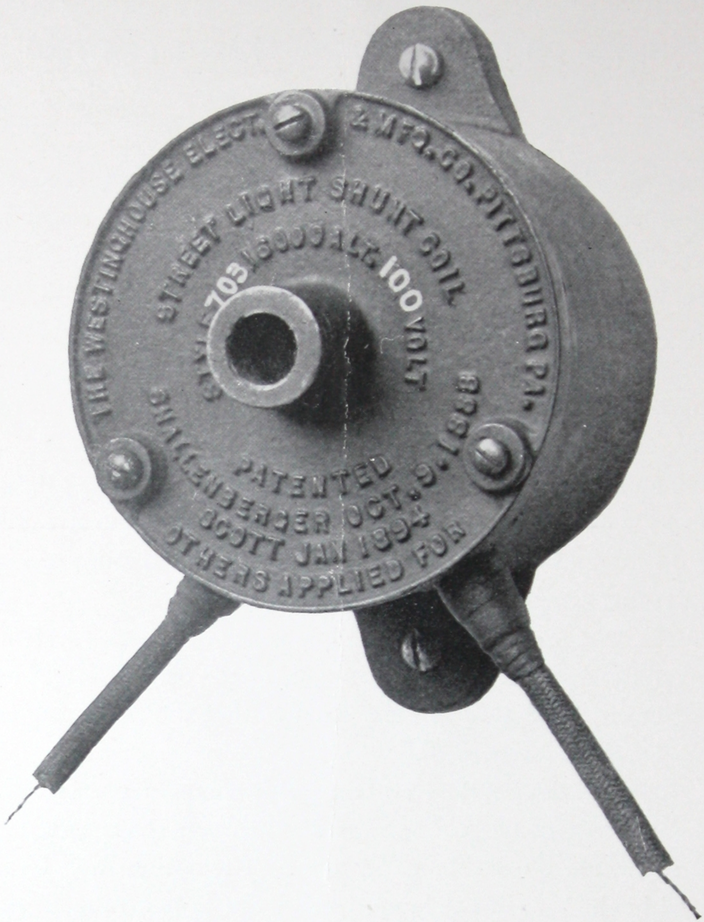
The multiple system of distribution for incandescent lighting, such as is generally used in buildings, is not suited to street lighting on account of the extra wiring and large amount of copper required as compared with the series system.

The first problem in the development of the series system was the maintenance of the circuit in spite of the destruction of one or more lamps belonging to the system so that the remaining lamps should continue in service.

An early device, and still in quite common use is the film cut-out, which consists of two contacts bridging the lamp terminals and separated by a thin paper film. The cut-out was formerly placed in the base of the lamp, but in the best arrangement the cut-out is located in the lamp socket. When a lamp is destroyed the film is punctured and the short circuit across the lamp terminals, thus produced, maintains the series circuit whose resistance had been reduced, and current increased by an amount corresponding to one lamp.

The need for a regulator for controlling the current thus becomes apparent.

The first form of regulator was the bank-board, an arrangement of resistance in the form of lamps which could be cut in or out of circuit until the ammeter indicated the proper current. This method was expensive and wasteful.



Street Light Shunt Coil.

The Stillwell regulator and the Thompson-Houston dimmer (which is simply an adjustable choke coil) were also used, but like the bank-board, they were non-automatic and so required an attendant.

A complete solution of the problem would thus provide a path for the current in case of lamp failures, and prevent any abnormal rise sufficient to endanger the lamps. The first system for performing these two functions automatically was the Westinghouse shunt box system.

Shunt Box System.—The shunt box consists of a single coil of wire wound within a complete magnetic circuit of laminated iron and the whole enclosed in an iron box. This device, as its name implies, is connected in shunt, one box to each lamp of a series (Fig. I), so that when the lamp fails the circuit is maintained through the shunt box, which then carries the total current. Under normal conditions the counter E. M. F. of the shunt

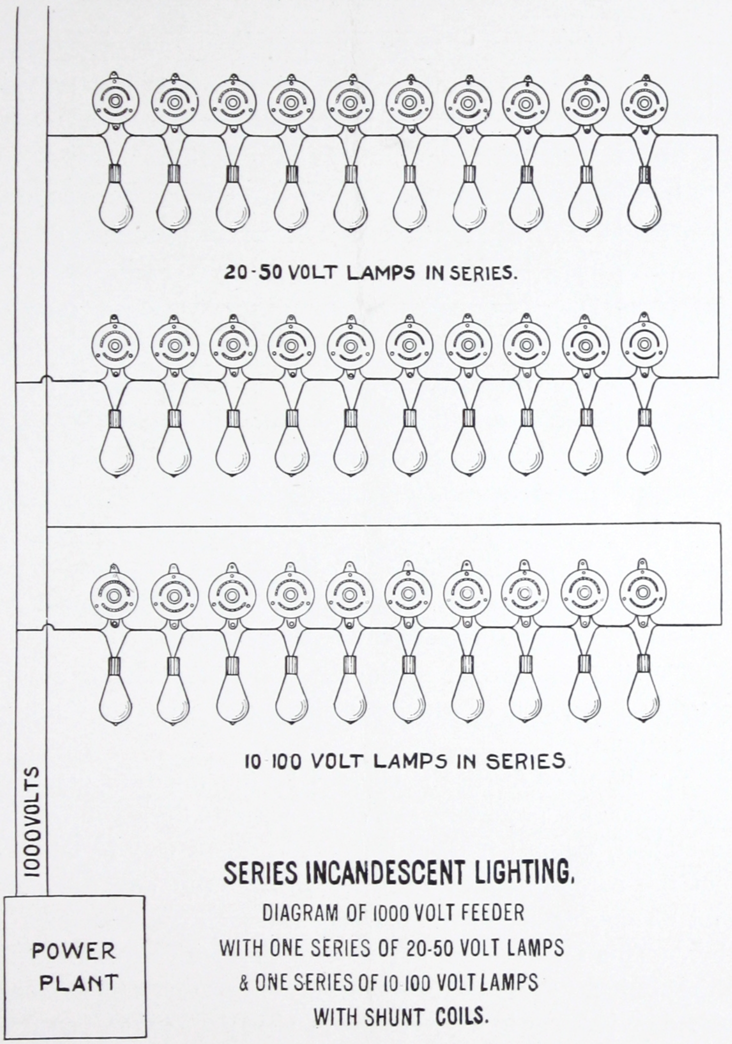


FIGURE I.

box is practically equal to the voltage impressed upon it, so that the magnetizing current taken is extremely small. When a lamp fails, the full line current is forced through the shunt box, which maintains the line current at practically its normal value until about 30 per cent. of the lamps are turned out, after which any further reduction in the number of lamps will rapidly reduce the line current. (Fig. II.)

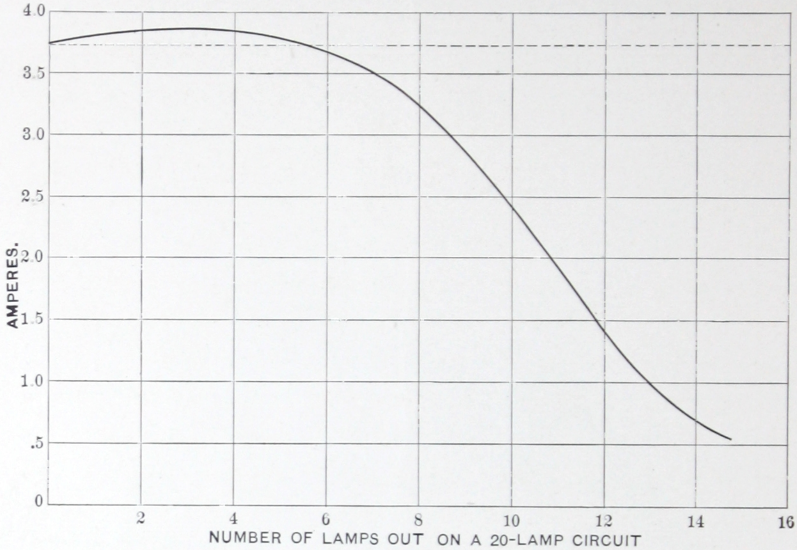


FIGURE II.

To bring the system back to its normal working conditions, it is only necessary to replace the broken lamps.

The diagram shows how the lamps and shunt boxes are connected in loops, each of which is a single series circuit similar to an arc circuit.

The lighting district is covered by the requisite number of loops, which are preferably served by separate lines controlled at the station, though if more convenient, loops may be taken off from the regular supply mains, starting from any convenient point on one main and terminating wherever convenient on the other. This system does not require that both wires be carried to the station. A central distributing box or several small boxes (placed on poles or in any convenient situation) may be used as a point from which loops may radiate.

A single loop of larger or smaller C. P. lamps may, of course, be operated without affecting the other circuits. The independence of different parts of the lighting system is striking and useful. As an example, advantage of this feature may be taken to operate high C. P. lamps in the business portion of a town and smaller C. P. lamps in the outskirts and residence portion.

Sometimes it is desired to operate lamps differing in C. P. on the same circuit. This may also be done by selecting lamps of the same current consumption as the circuit and using with them shunt boxes designed for their voltage. When lamps of but one voltage are available, these, too, may be operated on the same circuit with lamps of different C. P. and different current consumption. A special shunt box is used for this purpose, designed so that, for example, 50 C. P. lamps may be used along one or two squares and 25 C. P. lamps for the rest of the circuit. Under such conditions, one 50 C. P. unit (lamp and shunt box) would replace two 25 C. P. units of the regular circuit.

It should be noted that since each lamp requires approximately 50 or 100 volts (standard lamps assumed) a nominal 1100-volt circuit will take care of twenty-two 50-volt or eleven 100-volt lamps, and circuits of other voltages a proportionately greater or less number of lamps.

It is often desired to operate a few special circuits consisting of a number of lamps different from that suitable to the circuit voltage. This is done by using an auto-transformer with taps on the winding to give the proper voltage required for the special circuits. The standard design of auto-transformers provides for eight special voltages. The nominal 1000-volt auto-transformers are arranged with taps to give 750, 800, 850, 900, 950, 1000, 1050, 1100 and 1150 volts, corresponding respectively to circuits of 15, 16, 17, 18, 19, 20, 21, 22 and 23 lamps of 50 volts each. The nominal 2000-volt auto-transformers have taps to give 1500, 1600, 1700, 1800, 1900, 2000, 2100, 2200 and 2300 volts corresponding respectively to circuits of 30, 32, 34, 36, 38, 40, 42, 44 and 46 lamps of 50 volts each. The losses in the auto-transformers are hardly appreciable and are of no consequence.

A small switchboard is furnished in conjunction with the auto-transformer, the combination being known as the "control outfit." By means of this outfit the proper voltage connection corresponding to any special number of lamps is made. The arrangement of the control outfit is indicated in the diagram Fig. III. Special outfits may, of course, be used where the standard designs do not meet the requirements.

The use of standard high efficiency lamps of low current consumption requires high voltage circuits if a larger number of lamps are to be operated in a single series. With this system the standard low current lamps are operated on moderately low voltages without any increase of wiring over a single series high voltage circuit carrying the whole number of lamps. Another convenient feature of this system is that in case of trouble, only a single circuit need be cut out, and thus only a small portion of the lighting will be interrupted, while on a long series circuit constituting all or a large part of the lighting system, a local trouble might cause an interruption of the whole or a large portion of the service. Or a more serious accident to a single series circuit might put the regulator out of commission and result in a long continued inactivity, such would not occur with the shunt box system unless the supply system were disabled, since each lamp and shunt box is a complete unit independent of the rest.

Small enclosed fuses for protecting the loop circuits may be used when deemed advisable. Such fuses will open the circuit in about five seconds with an increase of 20 per cent. in current, thus affording very good protection to the lamps against shorts on the system.

To summarize: The notable features of this distributing system appear as follows:

There are no moving parts, contacts or anything mechanical. The action of the shunt box is entirely automatic, certain and instantaneous. Each box is a unit in itself, assuming the place of a defective lamp, or again assuming its normal function when the lamp is replaced without any adjustment whatever. Any number of lamps may be operated, the only limit being the capacity of the

generating station. Lamps of different candle powers may be operated on circuits by themselves or with lamps of greater or less C. P., current consumption, or voltage. By means of the control outfits, special circuits carrying an odd number of lamps may be operated at the same high efficiency as the regular circuits. The system is adapted to circuits ranging from 1000 to 3300 volts, at which potentials line troubles are almost unknown. The percentage of current required to keep the shunt coils magnetized is very

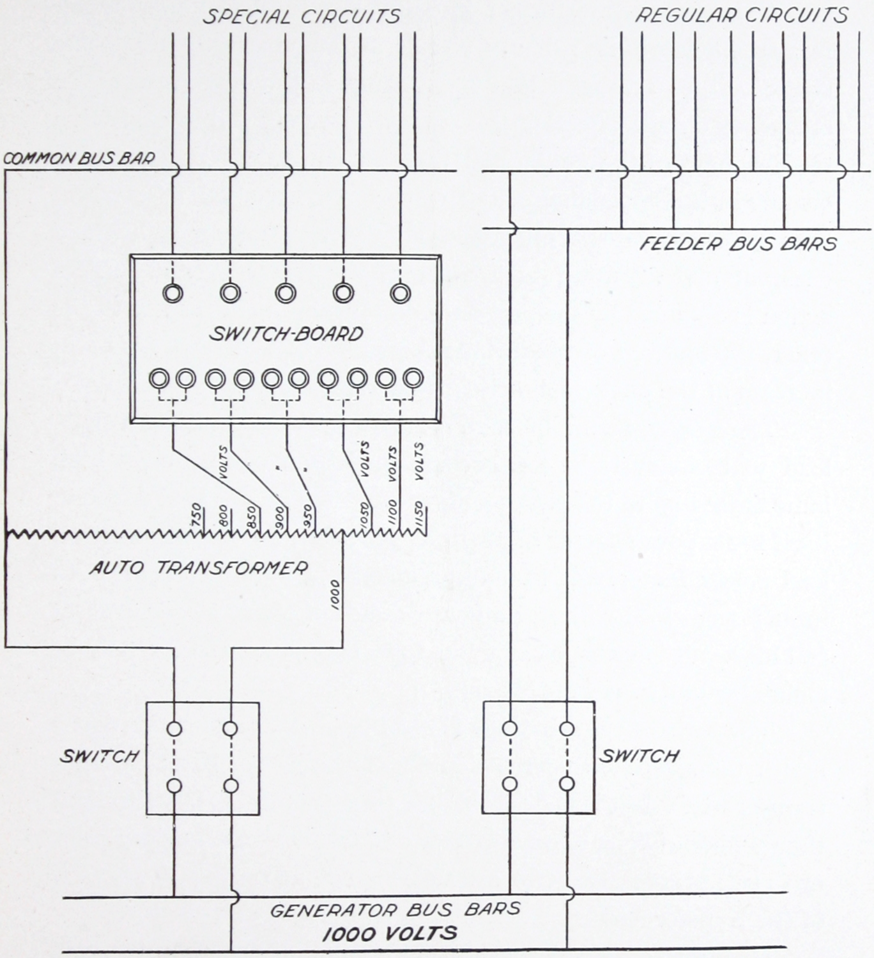


FIGURE III.
DIAGRAM OF AUTO-TRANSFORMERS AND SWITCHBOARD TO OPERATE FIVE SPECIAL CIRCUITS.

small and little energy is consumed for this purpose, hence the entire system operates at a high efficiency and power factor, which is maintained irrespective of the number of lamps used. This feature is peculiar to this system alone.

CONSTANT CURRENT REGULATOR SYSTEM

The repulsion coil type of transformers is designed to give a constant current and to insulate the line from the primary circuit.

This type of transformer is equivalent to the ordinary transformer, having in its primary circuit an automatically adjustable choke coil, so arranged that any change in the impedance of the secondary circuit affecting the current strength will cause such a readjustment of the choke coil that an equivalent and opposite change in the impedance of the primary circuit shall take place, thus maintaining the impedance of the transformer as a whole constant and resulting in a constant secondary current. This action is obtained by making one coil movable with respect to the other, the increase of the distance between coils corresponds to an increase of the choke coil action, and vice versa.

The power factor of such transformers operating at a light load will obviously be low because the load is one having a high inductance due to the choke coil action. On an arc load which in itself has a power factor of about 85 per cent., the transformer full load power factor will be approximately 73 to 78 per cent. An incandescent load will give a power factor of about 98 per cent. at full load. By means of suitable taps this power factor may be maintained at 70 per cent. load.

The ratio of the windings in this type of transformer determines their relative currents and voltages just as in an ordinary transformer. But it is desirable for constructural reasons to limit the number of coils to one primary and one or two secondary coils, or to two primary and two secondary coils, according to the size of the transformer.

Owing to considerations of cooling and insulating, transformers larger than 100 lights are usually designed for operation in oil; 25, 50 and 75 light transformers are often made oil-cooled.

The weight of the movable coil is balanced by a counterweight so adjusted that when the proper secondary current flows, the system is in equilibrium. Any change in the secondary current results in a corresponding change in the repelling force between the coils and the balanced system re-adjusts itself so that the current is again brought to normal. The range of constant current regulation of this type of transformer is from short circuit (no voltage output) with the coils at their maximum separation, to full voltage with the coils at their minimum separation.

The widest application of this type of transformer is found in arc lighting, although a large number are used for incandescent street lighting. When designed for operating incandescent lamps the secondaries are usually wound for approximately 1¾ or 3 amperes in order to use standard high efficiency lamps which are much cheaper and better than special high current lamps, such as are sometimes used on ordinary arc circuits.

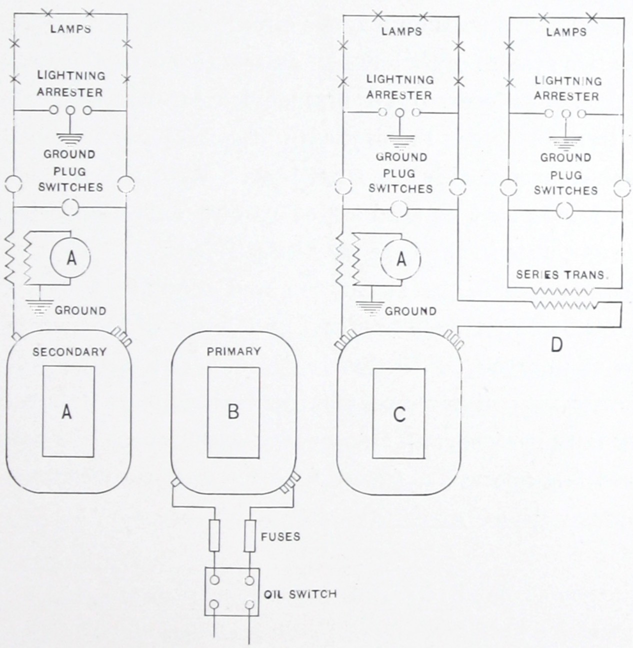


FIGURE IV.

Where arc and incandescent lamps are operated at different amperages from the same station, a regulator transformer may be wound with two secondaries (A-C Fig. IV), one for incandescent lamps and the other for arc lamps, just as is done when two separate arc circuits are operated from the same transformer.

If the arc load, as compared with the incandescent load, be small, a properly designed series transformer (D Fig. IV) placed in the incandescent circuit will deliver a constant current for the arc lamps and the regulator transformer will then take care of both the arc (D) and incandescent circuits (A and C).

A similar arrangement for operating incandescent lamps may be used to advantage on an arc circuit when a small load of incandescent lamps is to be carried.

By using a special shunt box just as with the regular shunt box system, lamps of different current consumption, C. P. and voltage may be operated on a series system. This device is of special value when it is desired to operate a limited number of extra large C. P. lamps on a series circuit of smaller lamps.

A series system must have an automatic cut-out at each lamp to take care of failures. The best device for use with constant current transformers is the film cut-out, preferably located in the lamp socket instead of in the lamp base. With this arrangement standard lamps may be used and the extra expense of the lamps with the cut-outs in the base may be avoided.

A comparison of the shunt box and regulator series system based on the approximate first cost and losses of the two systems for both 25 and 50 C. P. lamps is given. The line construction, lamp renewals, maintenance and depreciation are taken as the same for both systems and 2-ampere, 4-watt lamps are assumed; lamps 200 feet apart, No. 6 wire used for line, 2.1 ohms per mile.

FIRST COSTS

25 C. P.

	Regulator System				Shunt System		
K. W.	Trans.	Sockets and Lamps	Total	Shunts	Sockets and Lamps	Total
5	$200 00	$ 57 50	$257 50	$187 50	$22 50	$210 00
10	250 00	115 00	365 00	375 00	45 00	420 00
20	350 00	230 00	580 00	750 00	90 00	840 00

50 C. P.

5	$200 00	$ 28 75	$228 75	$ 93 75	$11 25	$105 00
10	250 00	57 50	307 50	187 50	22 50	210 00
20	350 00	115 00	465 00	375 00	45 00	420 00

LOSSES IN WATTS

25 C. P.

K. W.	Trans.	Line	Total	Shunt Boxes	Line	Total
5	310	16	326	250	16	266
10	540	32	572	500	32	532
20	890	64	954	1000	64	1064

50 C. P.

5	310	8	318	125	8	133
10	540	16	556	250	16	266
20	890	32	922	500	32	532

The table of first costs shows that, using 25 C. P. lamps, the shunt box system is the cheaper for 5 kw. (50 lamps) and that at 10 kw. (100 lamps) the regulator system is the cheaper. Either system would cost about the same for 7 kw. capacity.

The 50 C. P. lamps are more favorable to the shunt box system, it being decidedly cheaper for the three capacities considered (5, 10 and 20 kw.).

The losses of the regulator system are greater than the shunt box system at 5 and 10 kw. and up to about 12 kw., for 25 C. P. lamps, but at 20 kw. the shunt box system has the greater losses. Using 50 C. P. lamps, the shunt box system has

less than one-half the losses of the other system for 5 and 10 kw. capacities, and but about 0.6 as much at 20 kw.

If high current special lamps are used on the regulator system, the cost of renewals and line losses are greatly increased, so that it is strongly advisable to use standard lamps of moderate current consumption.

To summarize : Within the capacity of the regulator, any number of lamps of different candle power and voltage, but having the same current consumption may be operated, and lamps of different current consumption may also be operated on the same circuit if a special shunt box is provided for each.

The series transformer insulates the secondary from the high line voltage and makes another constant current circuit of the same or different current strength available from a single regulator transformer. Both arc and incandescent lamps may be operated from the same regulator.

The cost of the regulator system is less than the shunt system using 25 C. P. lamps for 7 kw. and higher capacities, and using 50 C. P. lamps for 20 kw. and higher capacities.

Losses are favorable to the shunt box system at 5 and 10 kw., but above 12 kw. the regulator system is the more efficient for 25 C. P. lamps.

Using 50 C. P. lamps the regulator system has about twice the losses of the other system for capacities of 20 kw. and below.

The power factor of the regulator system is high at full load and diminishes as the load is decreased.

GENERAL CONCLUSIONS

Based on first cost, the shunt box system is the cheaper for about sixty 25 C. P. lamps or for about one hundred 50 C. P. lamps. The losses of the shunt box system are lower at small capacities up to 12 kw. of 25 C. P. lamps, and much lower than the regulator system up to 20 kw. when using 50 C. P. lamps.

The shunt box system is more flexible for incandescent work, but where both arc and incandescent lighting is to be done the regulator system is preferable.

The power factor and efficiency of the regulator at full load is high and falls as the load is reduced, while that of the shunt system remains constant for all loads.

Considering cost and performance, the regulator system is inferior for small capacities, but superior for large capacities, depending upon the size of lamp used.

In some instances a station could use both systems to advantage. For example, when a few alley incandescent lamps were needed, the main load being arcs.

The final selection of a system for a particular locality will depend upon the nature of the service, whether it will be business or residential, whether thickly or thinly settled, what candle power lamps will be used, what the total number of lamps will be at the start and the future probabilities, what the importance of losses are and what the first costs are.

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